

Overbank Flow Condition in a River Section

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Abstract—When the flows in natural or man made channel sections exceed the main channel depth, the adjoining floodplains become inundated and carry part of the river discharge. Due to different hydraulic conditions prevailing in the river and floodplain of a compound channel, the mean velocity in the main channel and in the floodplain are different. This leads to the transfer of momentum between the main channel water and that of the floodplain making the flow structure more complex. Results of some experiments concerning the overbank flow distribution in a compound channel are presented. Flow sharing in river channels is strongly dependant on the interaction between flow in the main channel and that in the floodplain. The influence of the geometry on velocity and flow distribution and different functional relationships are obtained. Dimensionless parameters are used to form equations representing the over bank flow sharing in the subsections. The equations agree well with experimental discharge data and other published data. Using the proposed method, the error between the measured and calculated discharge distribution for the a compound sections is found to be the minimum when compared with that using other investigators.

Index Terms—Over bank Flow, flow interaction, horizontal interface, Flow distribution, Velocity distribution, Main channel, Flood plain

I. INTRODUCTION

During floods, a part of the river discharge is carried by the main channel and the rest is carried by the floodplains located to its sides. Due to different hydraulic conditions prevailing in the river and floodplain, mean velocity in the main channel and in the floodplain are different. This leads to the transfer of momentum between the channel section and the floodplain. At the junction region between the main channel and that of the floodplain [9] indicated the presence of artificial banks made of vortices, which acted as a medium for transfer of momentum. At low depths of flow over floodplain, transfer of momentum takes place from the main channel flow to the floodplain leading to the decrease in the main channel velocity and discharge, while its floodplain components are increased. And at higher depths over floodplains the process of momentum transfer reverses, the floodplain supplies momentum to the main channel. Information regarding the nature of flow distribution in a river channel is needed to solve a variety of river hydraulics and engineering problems such as to give a basic understanding of resistance relationship, to understand the mechanism of sediment transport etc.. The flow and velocity distribution in compound sections have been investigated by many investigators (e.g. [3], [4], [5], [1], [6], [7], [2], etc.). The zonal or sub-area flow distributions in the main channel and floodplain of compound channel mainly depend on the channel geometry and flow parameters. An investigation is made to obtain the flow distribution between lower main

channel, and floodplain for compound sections.

II. EXPERIMENTAL SETUP AND PROCEDURE

Using the fund from the department of science and technology, Government of India, the authors have built a numbers of flumes in the water resources and hydraulic engineering laboratory of the Civil Engineering Department of the National Institute of Technology Rourkela, India. Within the flumes, experimental channels with floodplains are built using Perspex sheets. Details of the geometrical parameter and hydraulics parameter of the experimental channels are given at Table 1 and Table2 respectively.

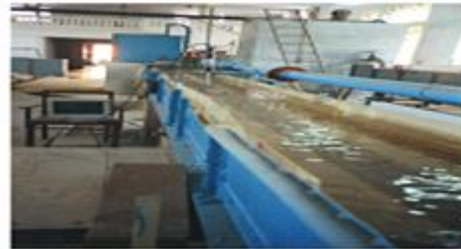


Photo. 1. Experimental Set up for the compound

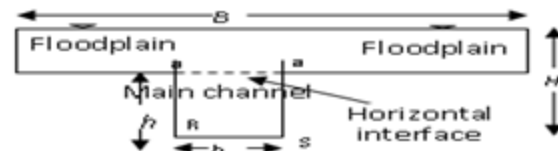


Figure 1. Division of a compound section into sub areas by an assumed vertical interface.

A recirculating system of water supply is established with pumping of water from an underground sump to an overhead tank from where water could flow under gravity to a stilling tank. From the stilling tank water is led to the experimental channel through a baffle wall. A transition zone helped to reduce turbulence of the flow water. An adjustable tailgate at the downstream end of the flume is used to achieve uniform flow over the test reach in the channel for a given discharge. Water from the channel is collected in a volumetric tank (Photo. P 3) for measuring the flow discharge, from where water runs back to the under ground sump, this establishing a closed circuit of flow. The channel sections are made from Perspex sheets for which the roughness of floodplain and main channel are taken as smooth and identical. The observations are made at the section of maximum curvatures (bend apex) of the meandering channel geometries. The measuring devices consist of a point gauge mounted on a traversing mechanism to measure flow depths having a least count of 0.1 mm. Point velocities are measured using a 16-Mhz Micro ADV (Acoustic Doppler Velocity-meter) having least count of 0.001m/s. Guide rails are provided at the top of the experimental flume on which a traveling bridge is moved in the longitudinal direction of the entire experimental channel. The point gauge and the micro-ADV attached to

the traveling bridge can move in both longitudinal and the transverse direction of the experimental channel at the bridge position.

TABLE I. GEOMETRY PARAMETERS OF THE EXPERIMENTAL COMPOUND CHANNELS

S/N	Item Description	Compound channel
1.	Geometry of Main channel section	Rectangular
2.	Main channel width(b)	120 mm
3.	Bank full depth of main channel	120 mm
4.	Top width of compound channel (B)	440 mm
5.	Slope of the channel	0.0019
6.	Ratio of top width (B) to channel width (b) = α	3.667
7.	Sinuosity	1.00
8.	Flume size	0.45m×0.4m ×12m long

TABLE II. FLOW AND FLOW DISTRIBUTION FOR OVER BANK FLOW AT BEND APEX OF EXPERIMENTAL CHANNELS.

Channel type	Run No.	Relative Depth (β)	Total Discharge (cm ³ /s)	Flow in Main Channel (Q _{lmc}) (cm ³ /s)	% of Flow in Main Channel (%Q _{lmc})
(1)	(2)	(3)	(4)	(5)	(6)
Compound Channel $\alpha = 3.666$	S13	0.15	10007	7305	73
	S15	0.21	13004	8805	67.71
	S17	0.30	19861	12318	62.02
	S18	0.36	25329	13151	51.92
	S19	0.41	30844	17131	55.54
	HM25	0.27	44412	14039	31.61
	HM27	0.28	48474	14838	30.61

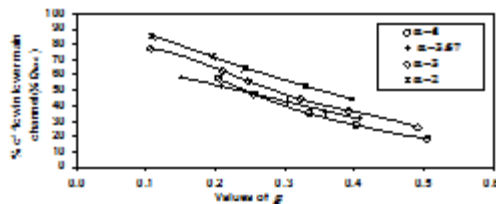


Figure 2 Variation of percentage of flow in main channel and lower main channel with relative depth for straight compound channels

The micro-ADV readings are recorded in a computer placed besides the bridge.

III. OVERBANK FLOW DISCHARGE RESULTS

Due to transfer of momentum between floodplain and main channel, the percentage of flow carried by the main channel with depth does not follow simple area ratios. At lower depths of flow over floodplain, the difference between percentage of flow in main channel and percentage of area of main channel is positive indicating that the main channel carries a greater percentage of flow than the simple area percentage. As the depth of flow over floodplain increases, the percentage of flow in main channel reduces. Plots of the isovels for the longitudinal velocities are used to obtain the area-velocity distributions that are subsequently integrated to get the discharge of the main channel and floodplains sub-areas separated by assumed vertical interface planes. The total discharge of the compound channel is used as a divisor to

calculate the percentages of discharge carried by the main channel and floodplain sub areas or zones. When a horizontal interface is used, the area of main channel is denoted by the area aRSa (Fig. 1). The flow percentage carried by this area is represented as %Q_{lmc} with depth ratio [$\beta = (H-h)/H$] for the compound channels are given in Table 2.

IV. THEORITICAL ANALYSIS AND MODEL DEVELOPMENT

From investigations it is a well known fact that, in overbank flow conditions of a river channel, there are two significant dimensionless channel geometries i.e. width ratio (α) and the relative depth (β) that effects the flow distributions in a river. Therefore for an overbank river flow under uniform conditions, the percentages of ratio of flow in main channel to the total flow can be written as

$$\% Q_{lmc} = \phi(\alpha, \beta) \quad (3)$$

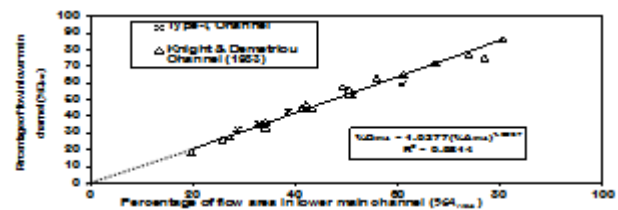


Figure.3 Variation of percentage of flow in lower main channel (%Q_{lmc}) against corresponding area of lower main channel for a compound channels

where %Q_{lmc} = the percentage of flow in the main channel subsection of a compound channel obtained by the imaginary horizontal interface plains of separation. Knight and Demetrious [3] have presented an empirical equation for flow carried by the main channel (%Q_{lmc}) as

$$\% Q_{lmc} = \frac{100(1-\beta)}{[(\alpha-1)\beta+1]} + 300 \left(\frac{\alpha-1}{\alpha} \right)^{1.25} (5.3\beta)^2 e^{-15.9\beta} \quad (4)$$

where α and β have their usual meanings defined before. Patra and Kar [8] modified equation (4) for their meandering compound channel and proposed %Q_{lmc} as

$$\% Q_{lmc} = \frac{100(1-\beta)}{[(\alpha-1)\beta+1]} + 300 \left(\frac{\alpha-1}{\alpha} \right)^{1.25} (5.3\beta)^2 e^{-15.9\beta} [1 + 36\beta L_n(S_r) / \delta] \quad (5)$$

where S_r = the sinuosity of the meandering channels and δ = the aspect ratio of main channel = b/h , b = width of main channel and h = bank full depth of main channel. Adequacy of equations (4 and 5) for flow distribution in straight and meandering compound channel for the range of α up to 5.25 are discussed by the respective authors. For channels having higher width ratio like, equation (5) gives higher percentages of error between observed and calculated discharges. Though the equation gives satisfactory results for low width ratio channels ($\alpha=2.00$) and lesser satisfactory for higher width ratio channels ($\alpha=4.0$). Using the present compound channel data, further analysis is made here to improve equation (4 and 5) for better generalization of equations. The equations developed by [3] and [8] shows that the percentage of flow carried by the lower main channel follow linearly to the simple area ratios (%A_{lmc}). To know the dependency, the variation of (%Q_{lmc}) with the area ratio (%A_{lmc}) for the present compound channel Type-I and the straight channel of Knight

and Demetrious (1983) are plotted in Fig.3.

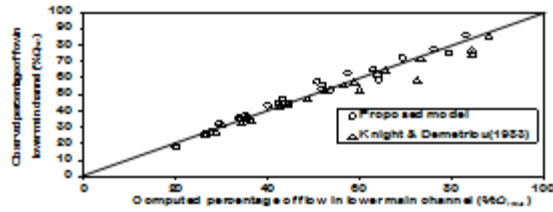


Figure.4 Variation of calculated versus observed value of flow distribution in Lower main channel ($\%Q_{lmc}$) for straight compound section

From the plots the best fit power function is found instead of a linear function. The equation is therefore modeled as

$$\% Q_{lmc} = 1.0277 (\% A_{lmc})^{1.0067} \quad (6)$$

Since for a rectangular main

$$\text{channel } \frac{A_{lmc}}{A} = \frac{1 - \beta}{(\alpha - 1)\beta + 1} \text{ substituting in (6a) we get}$$

$$\% Q_{lmc} = 1.0277 \left[\frac{100 (1 - \beta)}{(\alpha - 1)\beta + 1} \right]^{1.0067} \quad (7)$$

The variation of computed percentage of flow in main channel with the observed value of Type-I along with channels of Knight and Demetrious [3] is shown in Fig. 4. The figure proves the adequacy of the present model for overbank flow conditions of a compound river section.

CONCLUSIONS

The following conclusions are drawn:

1. The flow between the lower main channel and floodplain sub-sections of a compound river section are examined and a reasonable relationship to predict the sub-section discharge for the types of geometry is proposed.
2. A set of compound channel data of different width ratio varying from 2.00 to 4.00 and depth ratio tested up to 0.4 are studied. For a compound channels the important parameters effecting the flow distribution are relative depth (β) and the width ratio (α),

These dimensionless parameters are used to form general equations representing the total overbank flow percentage carried by lower main channel.

3. The proposed analytical model is simple but more reliable and found to give reasonable results for the compound channel of all types of geometry. The proposed equations give less error for the present channels. The models also have been validated well to the data of Knight and Demetrious [3].

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